BELLE FOURCHE RIVER FECAL COLIFORM ANALYSIS PROJECT FINAL REPORT SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM

Topical Report RSI-1882

prepared for

Belle Fourche River Watershed Partnership
1837 5th Avenue South
Belle Fourche, South Dakota 57717-2086

and

South Dakota Department of
Environment and Natural Resources

December 2007

RESPEC
CONSULTING & SERVICES

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Topical Report RSI-1882

by

Cory S. Foreman

RESPEC
P.O. Box 725
Rapid City, South Dakota 57709-0725

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EXECUTIVE SUMMARY

The Belle Fourche River, from the South Dakota/Wyoming border to near Fruitdale, South Dakota, is not meeting the water-quality standards for the beneficial uses assigned to this reach of the river. Because the water-quality standards are not being met, the reach is listed on the 2004 South Dakota Integrated Report for Surface Water Quality Assessment. The listing is based on water-quality samples that have high concentrations of fecal coliform bacteria. A total maximum daily load (TMDL) report for this section of the Belle Fourche River was completed for fecal coliform bacteria.

The purpose of the Belle Fourche River Fecal Coliform Analysis, which was sponsored by the Belle Fourche River Watershed Partnership (BFRWP), was to develop the TMDL for fecal coliform for the impaired segment of the Belle Fourche River. The objectives of the project were:

- Analyze historical water-quality data.
- Design and implement a water-quality monitoring program to determine fecal coliform bacteria sources.
- Develop duration curves to determine necessary load reductions.
- Analyze and prioritize best management practices (BMPs).

After analyzing the historical water-quality data and the water-quality data collected from the monitoring program, it was determined that the section of the Belle Fourche River that was monitored is not meeting the water-quality standards for the beneficial uses assigned to this reach of the river. Several bacteria source tracking samples were collected to test for the presence of human and cattle contamination in the river. These samples were negative for the presence of human or cattle contamination. Cattle are the most abundant form of livestock in the Watershed and have the most access to the river. However, since there was no direct evidence from bacterial source tracking samples collected on this project, of either human or cattle contamination, it must be assumed that a large portion of bacteria in the river is from natural sources (i.e., wildlife sources) in the Watershed.

FUNDING SUMMARY

PROJECT TITLE:	Belle Fourche River Watershed Assessment
SECTION GRANT NUMBER(S):	C999815-00, C999815-01, C999815-02
PROJECT START DATE:	April 10, 2001
PROJECT COMPLETION DATE:	April 30, 2006
FUNDING:	
TOTAL EPA GRANT BUDET:	$290,077
TOTAL MATCHING FUNDS BUDGET:	$151,162
TOTAL NONMATCHING FUNDS BUDGET:	$406,360
TOTAL BUDGET:	$784,264
BUDGET REVISIONS:	
319 funds added:	$ 29,500
604(b) funds added:	$ 33,835
TOTAL EXPENDITURES OF EPA FUNDS:	$290,077
TOTAL 319 MATCHING FUNDS ACCRUED:	$170,411
TOTAL EXPENDITURES (319 Funds and matching funds):	$460,488

SUMMARY OF ACCOMPLISHMENTS

The purpose of this preimplementation assessment was to determine the sources of fecal coliform bacteria in the Belle Fourche River Watershed and to define management prescriptions for identified nonpoint source critical areas in the Watershed. This project resulted in a total maximum daily load (TMDL) report for the listed reach of the Belle Fourche River for fecal coliform bacteria.

Fecal coliform water-quality standards are being exceeded in 52 percent of the samples collected in the last 5 years. Exceedences occurred in all flow ranges, including the lowest flows sampled. However, the highest percent of exceedences of the fecal coliform standard occurred at the higher flows with 25 percent flow exceedence rates. The low flow exceedences of the fecal coliform standard indicate a direct source of fecal coliforms to the river. The higher exceedence rate for high flows indicates storm events are contributing the largest load to the river during runoff events. Some evidence exists indicating fecal coliform bacteria are being stored in the sediments and being resuspended during flow increases. Specifically, a fecal coliform sample was collected during a water release from Keyhole Reservoir that exceeded the water-quality standard. Since this increase in flow was not associated with watershed runoff, the high concentration most likely came from resuspension of stored bacteria in the river. Of the samples collected, no correlation between total suspended solids (TSS) and fecal coliform bacteria was found.

Based on samples collected on this project, it appears that natural background from wildlife is the largest contributor of fecal coliform bacteria in the Belle Fourche River. Bacterial source tracking was performed on samples collected on three different dates, and no evidence was found of fecal coliform from human or cattle sources. It is possible that domestic animals other than cattle, specifically domestic pets in the city of Belle Fourche, are contributing to the fecal coliform loading at a significant level. One set of samples collected upstream and downstream of the city of Belle Fourche showed a large increase in fecal coliform concentrations through town. This sample was also tested for human sources and none were found.

A 46-percent reduction of fecal coliform bacteria concentrations is required to bring the Belle Fourche River into compliance with the water-quality standards. This reduction is required for the Belle Fourche River upstream of the confluence of the Redwater, near the city of Belle Fourche, South Dakota. Best management practices (BMPs) are recommended in this report to control the delivery of fecal coliform bacteria in the Belle Fourche River.

ACKNOWLEDGEMENTS

The Belle Fourche River Watershed Partnership (BFRWP) would like to thank all those involved with this segment of the assessment of the Belle Fourche River Watershed for fecal coliform bacteria. The efforts of all those involved from the following organizations are greatly appreciated and have been essential to the success of this project.

Belle Fourche Irrigation District

Butte County Conservation District

Elk Creek Conservation District

Individual rancher, farmers, producers, and landowners within the Watershed

Lawrence County Conservation District

Natural Resource Conservation Service

South Dakota Department of Environment and Natural Resources

South Dakota School of Mines and Technology

United States Geological Survey

United States Bureau of Reclamation

United States Environmental Protection Agency

United States Fish and Wildlife Service

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1.0 INTRODUCTION

The Belle Fourche River is a natural stream that drains parts of Butte, Lawrence, and Meade Counties in South Dakota. The river flows into the Cheyenne River in Meade County and ultimately to the Missouri River. The Belle Fourche River Watershed is approximately 2,100,000 acres (3,300 square miles) in size in South Dakota and includes Hydraulic Units 10120201, 10120202, and 10120203. The primary city of Spearfish (population 8,606) is the largest municipality located in the Belle Fourche River Watershed. Other small communities in the Watershed include Deadwood (population 1,380), Lead (population 3,027), Sturgis (population 4,442), Belle Fourche (population 4,565), Fruitdale (population 62), Nisland (population 204), and Newell (population 646).

Land use in the Watershed is primarily agricultural grazing with some cropland. Sixty-seven percent of the Watershed is classified as either grasslands or pasture. Wheat, alfalfa, native and tame grasses, and hay are the main crops within the Belle Fourche Irrigation District (BFID) while some corn is grown as well. Some winter animal feeding areas are located in the Watershed. Gold mining is conducted in some headwater areas of the Watershed. Approximately 11 percent of the Watershed is managed by the United States Forest Service and 4 percent is managed by the Bureau of Land Management.

The Belle Fourche River, from the South Dakota/Wyoming state line to the United States Geological Survey (USGS) Gaging Station 0643600 near Fruitdale, South Dakota (Figure 1-1), is listed in the *2004 South Dakota Integrated Report for Surface Water Quality Assessment* [South Dakota Department of Environment and Natural Resources, 2004]. This segment of the Belle Fourche River has five beneficial uses: (1) fish/wildlife propagation waters, (2) limited contact recreation waters, (3) irrigation waters, (4) immersion recreation, and (5) warm water permanent fish life propagation. For a stream segment to be included in the report as an impaired waterbody, more than 10 percent (greater than 25 percent if less than 20 samples are available) of the water-quality samples in a stream segment must exceed the water-quality criteria for the beneficial uses of the stream segment. The impaired reach of the Belle Fourche River is not meeting the water-quality standards for immersion recreation. The Belle Fourche River impairments are caused by high concentrations of fecal coliform bacteria. This listing is based on South Dakota Department of Environment and Natural Resources (SD DENR) water-quality monitoring data from Water Quality Monitoring (WQM) Station 130.

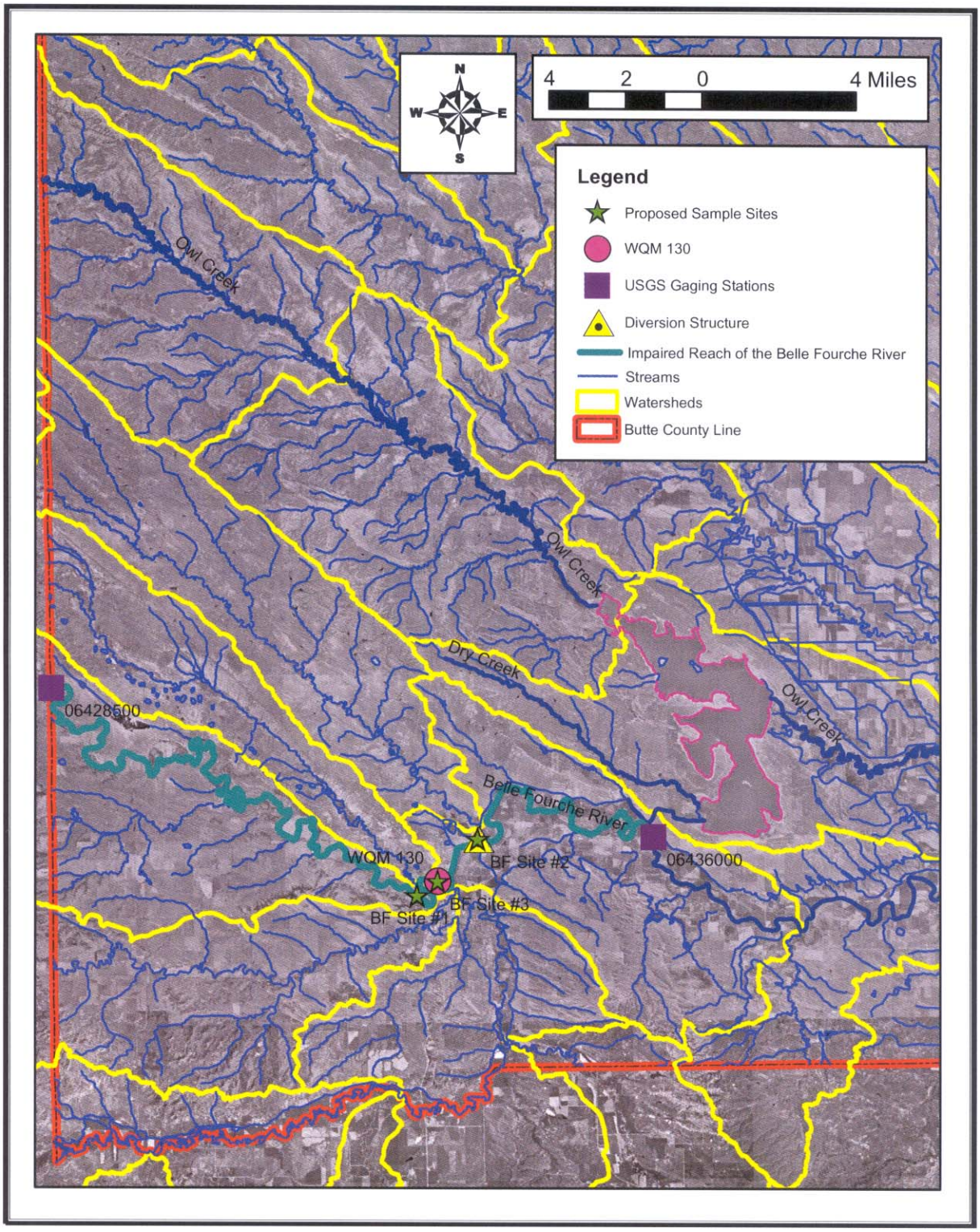

Figure 1-1. Belle Fourche River Study Area.

2.0 PROJECT GOALS AND OBJECTIVES

The project goal was to provide the sampling and analysis required to develop a total maximum daily load (TMDL) report for the segment of the Belle Fourche River impaired by fecal coliform bacteria. This was completed by performing tasks associated with the following four objectives:

Objective 1. Analyze historical water-quality data.

Objective 2. Design and implement a water-quality monitoring program to determine fecal coliform bacteria sources.

Objective 3. Develop duration curves.

Objective 4. Analyze and prioritize best management practices (BMPs).

Objective 1. Analyze historical water-quality data. The SD DENR and South Dakota School of Mines and Technology (SDSM&T) began collecting fecal coliform data in 1999. This data was the basis of the impairment listing of the Belle Fourche River for fecal coliform bacteria. This dataset was critical in understanding the loading and sources of impairment for fecal coliform bacteria. The analysis of this dataset was the basis for the sampling plan designed as part of Objective 2.

Objective 2. Design and implement a water-quality monitoring program to determine fecal coliform bacteria sources. The water-quality monitoring took place during the summer of 2004 and the spring and summer of 2005. Water-quality samples were collected at WQM 130 and upstream and downstream of the city of Belle Fourche (Figure 1-1). Additional samples were collected at WQM 130 to increase the size of the water-quality dataset at this site so that a more accurate analysis of water quality could be completed. Samples were collected upstream and downstream of the city of Belle Fourche to help determine what effect the city has on the water quality of the Belle Fourche River. Bacteria source tracking samples were collected during a storm event, during a flow increase caused by a release of water from Keyhole Reservoir in Wyoming, and during two "normal" base flow conditions for a total of four ribotyping samples at each site. During normal flow at WQM 130, 11 water-quality samples were collected from mid-July 2004 through August 2006. These samples were analyzed for total suspended solids (TSS), total dissolved solids (TDS), and fecal coliform. These samples were necessary to create a database of sufficient size to properly analyze the water-quality data at WQM 130. The TSS and TDS samples were used for a regression analysis with fecal coliform bacteria to determine if a statistical relationship between fecal coliform and TSS and TDS exists. In addition to the 12 routine samples collected at WQM 130, up to 4 additional samples were collected during high flows. Four samples were collected during storm events and one sample was collected during a flow increase caused by a release of water from Keyhole Reservoir in Wyoming. Turbidity, pH, dissolved oxygen, specific conductance, and water temperature were measured when each water-quality sample was collected.

Objective 3. Develop duration curves. A flow and a load duration curve was developed for WQM 130. Since WQM 130 is not at a continuous gaging station, the flow duration curve had to be generated based on estimated daily flows. The USGS operates gage stations on the Redwater River above Belle Fourche (USGS 06433000), on the Belle Fourche River downstream of WQM 130 (USGS 06436000), and on the diversion canal to Belle Fourche Reservoir (USGS 06434505). Using a simple mass balance between these stations,

daily flow estimates for WQM 130 were estimated. The validity of this method was verified by regressing the estimated flow versus the measured flow point at the site location for days when flow was measured at WQM 130. The results of this are described further in Section 3.1.3. The load duration curve was created by multiplying the flow duration curve by the fecal coliform criteria [Cleland, 2002]. Estimated loads were plotted on the load duration curve for each water-quality sample collected at WQM 130. Measured flows at WQM 130 were used for each individual loading estimate, except for seven samples collected by the SD DENR, where no flow data were available. For these seven samples, estimated flows were used. Only data points from 2001 to 2005, during the time period of May through September, are shown on the plot. The load duration curve was used to indicate under which flow conditions fecal coliform levels were exceeding the water-quality criteria.

Objective 4. Analyze and prioritize best management practices (BMPs). A BMP is defined by the Soil and Water Conservation Society as "a practice or combination of practices that are determined by a state or designated area wide planning agency to be most effective and practicable (including technological, economic, and institutional considerations) means of controlling point and nonpoint source pollutants at levels compatible with environmental quality goals" [Ritter and Shirmohammadi, 2001]. After the results from the monitoring plan were known, several BMPs were analyzed. The BMPs that are expected to be most effective at reducing fecal coliform concentrations in the Belle Fourche River are outlined in Chapter 7.0 of this report.

2.1 PLANNED AND ACTUAL MILESTONES, PRODUCTS, AND COMPLETION DATES

The project completion date for this project is April 30, 2006. Field sampling for this project began in July 2004 and continued through August 2005. Analysis of the results and the final report were expected to be complete by December 2005. The project completion date was extended to April 2006. A list of planned and actual milestones is shown in Table 2-1.

Table 2-1. Planned Versus Actual Milestone Dates

BFRWP Implementation	Planned Milestone	Actual Milestone
Objective 1. Analyze Historic Water-Quality Data	October 2005	December 2005
Objective 2. Develop and Implement Monitoring Program	August 2005	August 2005
Objective 3. Develop Duration Curves	December 2005	March 2006
Objective 4. Analyze and Prioritize Best Management Practices	December 2005	April 2006
Write TMDL	December 2005	April 2006
Project Complete	December 2005	April 2006

2.2 EVALUATION OF GOAL ACHIEVEMENT

This project was successful at accomplishing the project goals. A TMDL report was written based on the results of this project. BMPs were identified and recommended based on the results of the ribotyping. Since specific sources of fecal coliform bacteria were not identified (i.e., human sources, livestock sources), recommended BMPs are based on literature without a clear understanding of the specific sources of fecal coliform (i.e., avian versus mammalian wildlife).

3.0 MONITORING RESULTS

3.1 SURFACE WATER CHEMISTRY

The water-quality data were collected by SD DENR and SDSM&T at three locations along the impaired reach of the Belle Fourche River before the initiation of this project. SDSM&T Station BF1 corresponded to the USGS Gaging Station 06428500 (Belle Fourche River near the Wyoming/South Dakota state line). SDSM&T Station BF2 corresponded to the SD DENR WQM Station 130. SDSM&T Station BF3 corresponded to the USGS Gaging Station 06436028500 (Belle Fourche River near Fruitdale). Table A-1 in Appendix A provides a brief description of each monitoring site and a summary of the water-quality data. The data showed that the fecal coliform concentrations significantly exceeded the limits at Stations BF1 and BF2 [Hoyer, 2003; Splittstoesser, 2004]. The water-quality data from the lower end of the impaired reach (near Fruitdale, South Dakota) had one sample that exceeded the fecal coliform criteria. This site is downstream of the diversion structure that transfers most of the flow of the Belle Fourche River to the Belle Fourche Reservoir. A more detailed summary of this water-quality data is included in Table A-2 located in Appendix A.

Additional water-quality samples were collected at Station BF2 (WQM 130) to augment the dataset and to aid in the development of a TMDL. A total of 16 samples were collected during the summers of 2004 and 2005. Of these samples, four were collected shortly after precipitation events and one was collected during a high flow event from water being transferred from Keyhole Reservoir in Wyoming to the Belle Fourche Reservoir. For quality assurance/quality control (QA/QC) purposes, two duplicate samples were collected in the field and one blank sample was analyzed at the laboratory. The results from these samples are shown in Table A-3 located in Appendix A.

Nine of the samples collected during the 2004–2005 study exceeded the standard of 400 colony-forming units (cfu)/100 milliliters (ml) for fecal coliform bacteria. This represents a 56-percent exceedence rate. The samples from the previous 3 years at WQM 130 had an exceedence rate of 46 percent. Combining the data from the last 5 years, the fecal coliform bacteria exceedence rate was 52 percent.

Two samples were collected upstream and downstream of the city of Belle Fourche, where fecal coliform bacteria concentrations were measured. The first sample collected on August 23, 2004, contained concentrations of 93 most probable number (mpn)/100 ml upstream of Belle Fourche and 1,100 mpn/100 ml downstream of Belle Fourche. This represents a 1,083-percent increase in concentration. The concentrations from the second sampling were 455 mpn/100 ml upstream of Belle Fourche and 293 mpn/100 ml downstream

of Belle Fourche. This represents a 36-percent decrease in concentration. Based on these two samples, the impacts from the city of Belle Fourche are not clear. No conclusions can be drawn from these samples. Future sampling across this reach may improve the understanding of the impacts of the city of Belle Fourche.

3.1.1 Duration Curves

Figure 3-1 illustrating a flow duration curve for the site at WQM 130 (Station BF1). This site does not have daily flows available. However, the USGS operates a daily flow gage station (USGS 06436000, Belle Fourche River near Fruitdale) a relatively short distance, approximately 12 stream miles, downstream of the site location. In the reach of stream between WQM 130 and USGS 06436000 is a confluence of a major tributary stream, the Redwater River. The Redwater River has a gage just upstream of the confluence (USGS 0633000, Redwater River above Belle Fourche). There also is a diversion into the Belle Fourche Reservoir, out of the Belle Fourche River, between WQM 130 and USGS 06436000. The canal for this diversion has a USGS daily flow gage located on it (USGS 6434505, Inlet Canal above Belle Fourche Reservoir) as well.

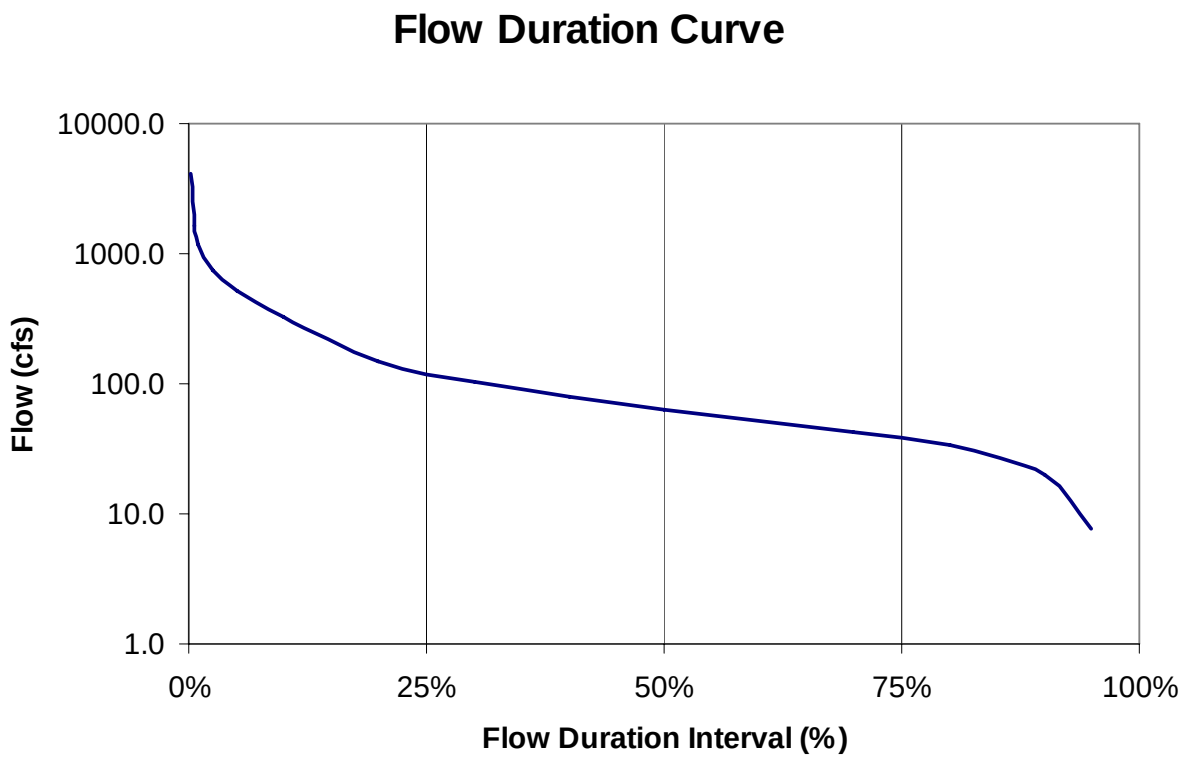

Figure 3-1. Flow Duration Curve for WQM 130 From 1994 Through 2005.

Using the data from these three locations, a daily flow record was created for WQM 130. The flow at WQM 130 was estimated as the flow at the Belle Fourche near Fruitdale plus the flow in the Inlet Canal above

Belle Fourche Reservoir minus the flow at the Redwater River above Belle Fourche. The estimated flows were regressed with measured flows at WQM 130 (see Figure 3-2). The data had a high correlation coefficient ($R^2 = 0.88$). The equation for the linear trendline was then used to predict the flow at WQM 130 for the period of record (1994 through 2005) data were available at the other three sites. Under low flow conditions, negative values were predicted for flow at WQM 130. The predicted flows were used to generate the flow duration curve as well as the FLUX loading estimates (discussed in Section 3.1.2).

Figure 3-3 shows a load duration curve from the fecal coliform water-quality samples from WQM 130. The flow duration was multiplied by the fecal coliform criteria to display the load criteria [Cleland, 2002]. The displayed line on the load duration curve represents the TMDL for the Belle Fourche River at WQM 130. Water-quality samples collected at WQM 130 are displayed on the plot as point data. Only samples from the last 5 years in the time period from May to September are displayed on the load duration curve. In South Dakota, the fecal coliform bacteria standard is in effect during the May through September time period [South Dakota Department of Environment and Natural Resources, 2004].

Water-quality samples collected during the last 5 years have a 52-percent exceedence of the water-quality standard of 400 cfu/100 mL. Exceedences occur over all flow regimes. In the dry end of the load duration curve, greater than 75-percent flow duration, 33 percent of the samples exceeded the water-quality criteria. Only one sample was collected from 50 percent to 75 percent of the flow duration interval, which was greater than 400 cfu/100 ml. The interval from 25-percent to 50-percent flow duration had six samples, of which 67 percent of the samples exceeded the criteria. Four samples were collected in the high flow rates, greater than 25 percent of the flow durations, of which three, or 75 percent, exceeded the criteria.

It is clear that higher percent exceedence occurs during high flow events. A large percentage of the load occurs during high flow, runoff events. However, there is a constant loading during low flow events contributing to exceedences of the water-quality criteria. The loading at low flow conditions represents sources from direct loading to the stream or from sources in close proximity to the Belle Fourche River.

3.1.2 Loading Estimates

Average annual loads were computed using the FLUX computer model [Walker, 1999] for WQM 130 (Belle Fourche River in Belle Fourche) and WQM 23 (Redwater River near Belle Fourche). FLUX modeling was performed to establish a relationship between fecal coliform bacteria and discharge and to use this relationship to attain the best possible estimates for the annual loads at each station. Data for the modeling came from the SD DENR and USGS.

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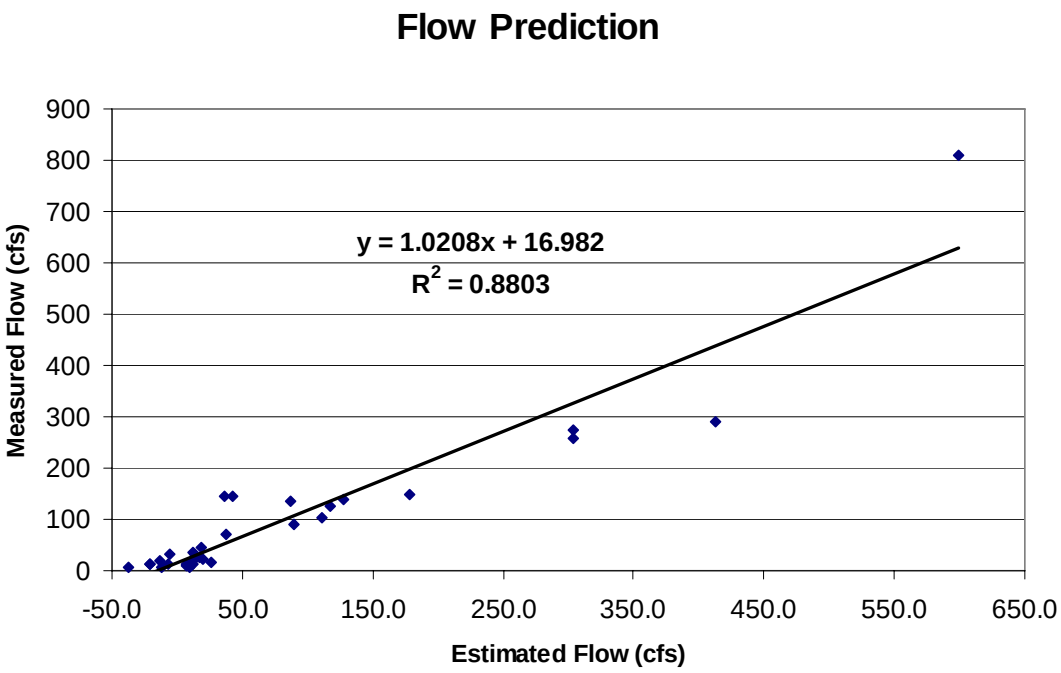

Figure 3-2. Estimated Versus Measured Flow Used for Predicting Discharge at WQM 130.

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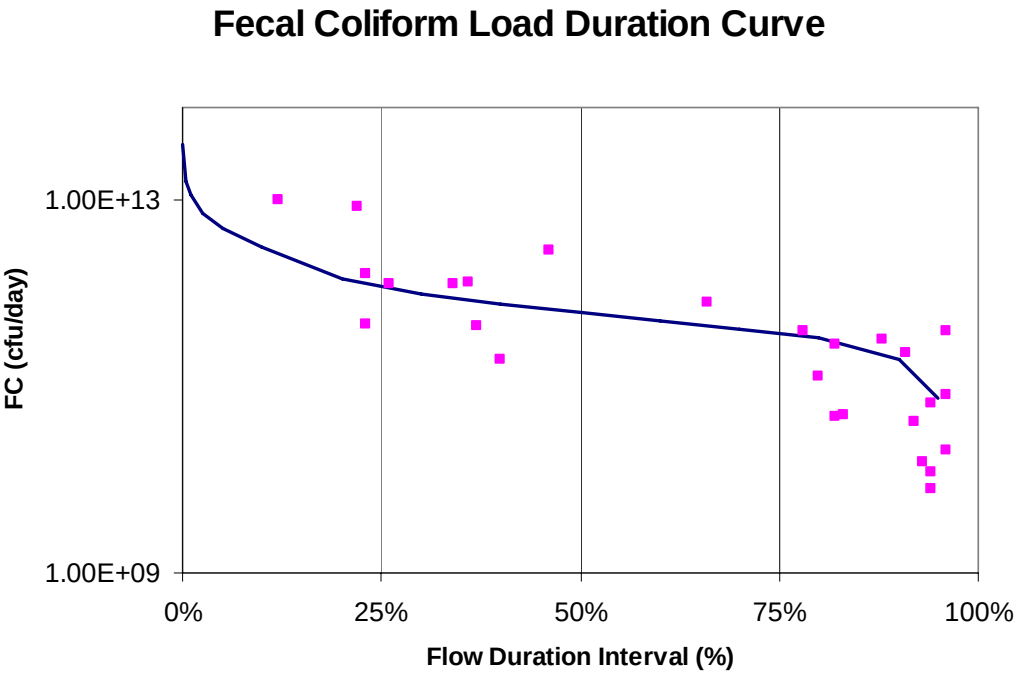

Figure 3-3. Load Duration Curve for Fecal Coliform Samples Collected at WQM 130 in the Last 5 Years in the Months of May Through September.

The procedure used was the typical application sequence suggested in the FLUX user manual [Walker, 1999]. The FLUX model requires two separate data files for modeling annual loads; the first is a file containing the complete flow record available and the second file is the water-quality data for the parameter being modeled along with the flow data for the date sampled. Predicted daily flows for WQM 130 (described in Section 3.1.1) were used for FLUX modeling flow record. Measured instantaneous flow was used in the water-quality data file for most samples. Of the 26 samples, 7 did not have measured flow at the time of sampling. Predicted flows were used for these samples in the water-quality data file. The model is only capable of handling 8,000 data points for discharge and 900 data points for water quality. The dataset used did not contain more than the maximum number of data points, so the complete dataset was used for both water quality and discharge.

The modeling sequence that was followed is listed below:

- Enter the proper data files for the site and parameter being modeled.
- Run a comparison of the data files for adequacy of the water-quality sampling flow range compared to the total flow record.
- Calculate loads using the six different regression methods incorporated into the model taking special note of the loading values as well as the coefficients of variation.
- Regress the water-quality data versus the flow record.

When importing data files, units of the model need a user-specified conversion factor to convert the units of flow and water-quality data to the required units for the model. The FLUX model uses flow values expressed as cubic hectometers per year (hm^3) and concentration values expressed in milligram per cubic meter (mg/m^3). The flow data for WQM were estimated as cubic feet per second, which requires a conversion factor of 0.8937 to convert to hm^3/year. Fecal coliform data were in units of cfu per 100 ml (cfu/100 ml). The cfu is not a unit of mass, which is required for FLUX modeling. This is a special case of modeling where mass flux is not involved. In order to address this problem, it was assumed, for the sake of calculation, that 100 cfu equaled 1 milligram (mg). Therefore, a conversion factor of 100 was used for modeling fecal coliform. This converted the fecal data to 100 cfu/m^3, while the model labeled the data as mg/m^3. Therefore, when reviewing the modeling results, it is important to recognize that where units are reported in kilograms (kg), it is necessary to convert back to colony-forming units using the conversion factor of 1.0×10^8 cfu= 1 kg. The modeling output results can be seen on in Appendix B.

No correlation between flow and fecal coliform concentration was found by the model at either site (R^2 = 0.11 for WQM 130 and R^2 = 0.15 for WQM 23). Therefore, Method 2, flow-weighted average concentrations times the mean flow over the averaging period, was used for the loading estimates. When flow and concentration are unrelated or weakly correlated, Method 2 enters the least amount of bias of the FLUX modeling methods. A mean annual load of 1.01×10^{15} cfu/year for WQM 130 and 9.81×10^{13} cfu/year for WQM 23 was estimated from the FLUX modeling. It should be noted that 54 percent of the total flow volume at WQM 130 occurs at flow rates higher than the maximum flow rate sampled for the samples used for the FLUX modeling. This large volume of water that was not sampled may have led to an underestimation of the annual average load. At WQM 23 only 19 percent of the total flow volume occurred above the maximum sampled flow rate, for samples used in the FLUX modeling.

3.1.3 Regression Analysis

Fecal coliform concentrations were regressed against TSS and TDS to see if any relationship existed between the parameters. No correlation existed for TSS ($R^2 = 0.04$) or for TDS ($R^2 = 0.09$), indicating fecal coliform is not being attached to solids nor suspended in the waterbodies as a function of solids loading.

3.1.4 Bacteria Source Tracking

Samples were collected on three different dates for bacteria source tracking: August 23, 2004; May 9, 2005; and July 5, 2005. In addition to sampling at WQM 130, samples were collected upstream and downstream of the city of Belle Fourche for bacteria source tracking on all three dates. Three different methods were used for bacteria source tracking for this project. On August 23, 2004, an E. coli. ID™ test was run on samples from all three locations. On May 9, 2005, a Human Bacteroidetes ID™ test was run on samples from all three locations. On July 5, 2005, a Human Bacteroidetes ID™ test and a Cow E. coli ID test was performed on samples collected from samples collected upstream and downstream of the city of Belle Fourche. No bacteria source tracking test was run on the sample collected at WQM 130 on July 5, 2005, since an additional test was run on samples from the other two sample locations. All bacteria source tracking samples were analyzed by Source Molecular in Miami, Florida.

An E. coli. ID™ test, often referred to as a ribotyping test, uses a genetic fingerprint that comes from genes that code for ribosomal ribonucleic acids of E. coli. to identify the source as either human or animal. This test does not distinguish cattle from other animal sources. A Human Bacteroidetes ID™ test uses organisms from the phylum *Bacteroidetes* as indicator species, instead of E. coli. to identify sources of bacteria. *Bacteroidetes* are anaerobes and are, therefore, indicative of recent fecal contamination. The Human Bacteroidetes ID™ test filters and identifies the bacteria from an entire sample versus identifying a subsample that is cultured on a Petri dish. Specifically, the Human Bacteroidetes ID™ test identifies contamination from human sources only. Similar to the E. coli. ID™ test, the Cow E. coli ID test uses E. coli as indicator species. The Cow E. coli ID test specifically identifies certain strains of E. coli. are specifically pathogenic in cattle to identify fecal contamination from cattle.

Source tracking samples from August 23, 2004, from all three sample locations indicated no contamination from human sources. Two isolates, one from upstream and one from downstream of the city of Belle Fourche, were indeterminate. All other samples were identified as being from animal sources. Similar to the August 2004 samples, the source tracking samples from May 9, 2005, showed no human sources of contamination. The Cow E. coli ID test was added for the final source tracking sampling on July 5, 2005, in order to identify the loading originating from cattle. The samples from the final source tracking sampling indicated no contamination from cattle or human sources. The complete list of results is shown in Table 3-1.

Table 3-1. Results of Fecal Coliform Source Tracking Analysis

Bacterial Source Tracking	Location	Energy Lab Fecal Coliform (CFU/100 ml)	Fecal Coliform (mpn/100ml)	Type of Test	Probable Source
08/23/2004	WQM 130	2,800	1,100	E. coli. ID™	5 isolates animal
08/23/2004	U/S B.F.	–	93	E. coli. ID™	4 isolates animal and 1 isolate ideterminate
08/23/2004	D/S B.F.	–	1,100	E. coli. ID™	4 isolates animal and 1 isolate ideterminate
05/09/2005	WQM 130	46	–	Human Bacteroidetes ID™	No Human Gene Biomarker Detected
05/09/2005	U/S B.F.	–	–	Human Bacteroidetes ID™	No Human Gene Biomarker Detected
05/09/2005	D/S B.F.	–	–	Human Bacteroidetes ID™	No Human Gene Biomarker Detected
07/05/2005	WQM 130	460	–	–	–
07/05/2005	U/S B.F.	–	455 (E.Coli)	Cow E. coli ID	No Cattle Gene Biomarker Detected
7/5/2005	D/S B.F.	–	293 (E.Coli)	Cow E. coli ID	No Cattle Gene Biomarker Detected
7/5/2005	U/S B.F.	–	–	Human Bacteroidetes "Quatification" ID™	No Human Gene Biomarker Detected
7/5/2005	D/S B.F.	–	–	Human Bacteroidetes "Quatificatio" ID™	No Human Gene Biomarker Detected

Based on the results of the bacteria source tracking, it appears that human sources of fecal coliform bacteria are not a major portion of the fecal coliform load in the Belle Fourche River. It also appears that cattle are also a small portion of the total fecal coliform load. No samples were identified from either human or cattle sources. However, because of the small sample size, the results do not mean that there is no loading of fecal coliform bacteria from either human or cattle sources. The results do suggest that neither humans nor cattle are a majority source of fecal contamination. Some evidence exists that the city of Belle Fourche has a

potentially large impact on fecal coliform loading. Probable sources of fecal contamination may come from domestic animals, other than cattle, from the city of Belle Fourche. The most significant source of fecal contamination appears to come from natural sources from wildlife, including warm-blooded mammals, such as deer and elk, and birds, such as waterfowl and turkeys.

3.2 GROUNDWATER

Groundwater was not sampled as part of this project.

3.3 STREAM, BIOLOGIC, OR PHYSICAL HABITAT MONITORING

There was no biological or habitat sampling as part of this project.

3.4 QUALITY ASSURANCE REPORTING

The water-quality samples collected for this project on behalf of the sponsor by the consultant were collected in accordance with the SD DENR Standard Operating Procedures for Field Samplers, Tributary and In-Lake Sampling Techniques [South Dakota Department of Environment and Natural Resources, 2003]. One field blank and two field duplicate samples were collected for the 16 water-quality samples collected at WQM 130. The field blank did not have detectable concentrations for any of the parameters tested at the laboratory (fecal coliform bacteria, TSS, and TDS). Precision of field duplicates was assessed using the Industrial Statistic (I) [South Dakota Department of Environment and Natural Resources, 2003], defined below:

$$I = \frac{(A - B)}{(A + B)} \times 100 \tag{3-1}$$

where:

$$(A - B) = \text{the absolute difference}$$

$$(A + B) = \text{the absolute sum.}$$

The industrial statistic for the replicate collected on May 15, 2005, was 9.09 percent. The industrial statistic from the second duplicate sample, collected on July 13, 2005, was 10.77 percent. Fecal coliform bacteria counts often vary greatly due to differences in bacteria growth on cultured media. Even though one sample exceeded 10 percent for the industrial statistic, precision for this project is adequate. Both duplicate samples occurred on the same side of the fecal coliform criteria (i.e., both samples were either above or below the criteria), which validates the percent exceedence values calculated from the data.

4.0 PUBLIC INVOLVEMENT

The Belle Fourche River Watershed Partnership (BFRWP) involved as many organizations, people, and funding sources as possible during this project. Some of the groups and/or organizations that the Partnership involved during this project include numerous local producers; ranchers and farmers; SD DENR; Butte, Meade, and Lawrence Counties, BFID; local Natural Resources Conservation Service (NRCS) personnel; Corps of Engineers; U.S. Bureau of Reclamation; USGS; United States Fish and Wildlife Service (USFWS); local towns, Wyoming Department of Environmental Quality (WYDEQ); and local conservation districts. These groups have all contributed time and/or money to the project and have been essential to the success of the project.

The four voting members of the BFRWP (BFID, Elk Creek Conservation District, Butte County Conservation District, and Lawrence County Conservation District) were essential to this project. The BFID worked directly with the Partnership to improve water quality related to TSS through irrigation efficiencies. This was one of the significant sources of TSS to the Belle Fourche River. By improving irrigation efficiencies, the amount of nonused water returning to intermittent streams and contributing TSS to the Belle Fourche River is reduced. The BFID worked with the BFRWP to install numerous BMPs and was willing to try new operational methods to improve efficiencies. The local conservation districts played an instrumental role in the education and outreach completed during the project.

4.1 STATE AGENCIES

The state agencies involved with this project included SD DENR and SDSM&T. The SD-DENR provided guidance and assistance in providing funding for this assessment. SDSM&T assisted with the field monitoring and sample collection.

4.2 FEDERAL AGENCIES

The federal agencies involved with this project included the NRCS, U.S. Environmental Protection Agency (EPA), and USFWS. All of these groups were important to the success of this project.

NRCS personnel have worked with local producers, ranchers, and farmers to encourage implementation of BMPs that focused on TSS concentrations in the Belle Fourche River and its tributaries. NRCS personnel have a good relationship with the individuals within the Watershed and a high level of trust. This has been instrumental in getting information to the local residents and support for this project.

The EPA provided the BFRWP with this grant. The USFWS was involved in the project meetings and planning. They did not provide funding for the current project; they have since committed funds to the implementation of BMPs related to the TSS TMDL previously completed for the Belle Fourche River.

4.3 LOCAL GOVERNMENTS

The Belle Fourche River Watershed Partnership was the lead organization for this project. Four public meetings were held during the duration of this project to discuss the work occurring in the Watershed. This work included this project but focused on the implementation project for TSS in the Belle Fourche River Watershed. These meetings were essential for getting all of the different local, state, and federal groups together to keep the project on schedule. The groups present at these meetings included local producers, farmers and ranchers; members of the Elk Creek Conservation District; the Lawrence County Conservation District and the Butte Conservation District; BFID; NRCS; SD DENR; USGS; Bureau of Reclamation; and USFWS.

5.0 EDUCATION AND INFORMATION

Public participation during this project was high. Public education and outreach completed during this project included sending out newsletters from the BFID, Elk Creek Conservation District, Butte County Conservation District, and the Lawrence County Conservation District. A Web site was developed by the consultant for the Partnership's education and outreach. This Web site is continually upgraded, informing the public of all aspects of TMDL work in the Watershed (*www.bellefourchewatershed.org*). Partnership activities were printed in local newspaper articles for soil and water stewardship. Also, four BFRWP meetings were held that were open to the public. The people that attended these meetings was able to voice their opinions and learn what projects the Partnership was working on.

6.0 ASPECTS OF THE PROJECT THAT DID NOT WORK WELL

The ribotyping methods that took place on this project were expected to be the same for all samples. Based on the results of the first sample and changes in procedures at the laboratory where the analysis was performed, the sampling procedure was changed slightly for each sample. For all three source tracking sampling events, a test for the presence of human bacterial indicators was conducted. The presence of human bacterial indicators were not detected in any samples.

It was assumed at the beginning of this project that a few samples upstream and downstream of the city of Belle Fourche would clearly show if Belle Fourche had a significant effect on fecal coliform loading. Only two samples were collected upstream and downstream of the city of Belle Fourche where concentrations were calculated at the laboratory. One of these samples showed a large increase in the fecal coliform concentration, while the second showed a decrease. Based on these samples, it is not clear what the overall impact the city of Belle Fourche has on the fecal coliform loading in the Belle Fourche River.

This project achieved its stated goals while each task was performed essentially as originally proposed. The project was expected to be complete in December 2005, while the actual completion date was April 2006. Overall, this project encountered very few unforeseen problems.

7.0 FUTURE ACTIVITY RECOMMENDATIONS

Further bacterial source tracking samples should be collected to better quantify the specific sources of fecal coliform in the Watershed. Recently, a fecal coliform TMDL was performed by SDSM&T on Whitewood Creek, a tributary to the Belle Fourche River downstream of Reach 8. Specific source tracking done as part of this project showed the majority (>80 percent) of fecal coliform is from avian sources. It has been speculated that much of this fecal coliform may come from the large turkey population living in the riparian areas of the Watershed. Additional fecal coliform samples should be collected upstream and downstream of the city of Belle Fourche. Some evidence was collected indicating a significant impact to water quality related to fecal coliform from the city of Belle Fourche.

The required reductions of fecal coliform concentrations may be achieved through the implementation of BMPs, including filter strips, riparian buffer strips, and riparian zone rehabilitation. These practices should be effective in reducing fecal loading from overland sources, both from cattle and wildlife. Additionally, if future source tracking shows clear evidence of a specific type of wildlife as being the major contributor of fecal coliform, BMPs coordinated with the South Dakota Game, Fish and Parks (SD GF&P) may be implemented, targeting management of the key species, focusing on possibly lowering population to appropriate numbers. Also, a litter control program should be implemented in the municipality of Belle Fourche. Litter control programs have been shown to reduce fecal loading in urban areas by up to 50 percent [Novotny and Olem, 1994]. Lastly, BMPs traditionally used for cattle sources of fecal coliform, such as fencing and exclusion, off-site watering, and rotational grazing, should be implemented. Even though no direct evidence from bacterial source tracking was documented for cattle sources of fecal coliform bacteria, the results are inconclusive because of the small sample size. As a majority of land use in the study area is grasslands and pasture, it is likely that there is some fecal coliform loading contributed by cattle sources. BMPs focused on cattle sources will lower the fecal coliform loading by reducing fecal coliform contamination from cattle sources or by reducing contamination from wildlife sources. Some BMPs focused on reducing fecal coliform concentrations, such as filter strips, will be effective in reducing fecal contamination from wildlife sources as well as cattle sources. Further monitoring of fecal coliform concentrations should continue to evaluate the effectiveness of BMP implementation. Additional bacterial source tracking may be beneficial for the future fecal coliform monitoring in order to further refine the BMP implementation process.

8.0 REFERENCES

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APPENDIX A

WATER-QUALITY DATA

Table A-1. Historical Water-Quality Monitoring Sites in the Upper Belle Fourche River Watershed in South Dakota

Station	Government Agency	Location	Latitude	Longitude	No. of Fecal Coliform Samples, No. of Samples Exceeding Criteria % Exceedence	Sample Frequency
06428500	USGS	WY/SD State Line	44.750	–104.047		
BF 1	SDSM&T	WY/SD State Line	44.750	–104.047	(17, 10, 58.8)	Monthly
WQM 130	DENR	Belle Fourche	44.675	–103.900	(9, 4, 44.4)	Variable
BF 2	SDSM&T	Belle Fourche	44.675	–103.900	(4, 2, 50.0)	Monthly
06436000	USGS	Near Fruitdale	44.691	–103.374		
BF 3	SDSM&T	Near Fruitdale	44.691	–103.374	(10, 1, 10.0)	Monthly

Table A-2. Detailed Water-Quality Data Less Than 5 Years Old From May 1 Until September 30 (Page 1 of 2)

Station	Count	Date	Fecal Coliform /100 ml	Government Agency[a]	Hydrologic Event
BF1	1	06/14/2001	**2,200**	SDSM&T	Routine
BF1	2	06/14/2001	**1,600**	SDSM&T	Routine
BF1	3	07/13/2001	**TNTC**[b]	SDSM&T	Irrigation
BF1	4	07/24/2001	**TNTC**[b]	SDSM&T	Rain Event
BF1	5	08/28/2001	230	SDSM&T	Routine
BF1	6	09/27/2001	30	SDSM&T	Routine
BF1	7	05/29/2002	260	SDSM&T	Routine
BF1	8	06/06/2002	**3,200**	SDSM&T	Keyhole
BF1	9	06/06/2002	**4,300**	SDSM&T	Keyhole
BF1	10	06/07/2002	**1,900**	SDSM&T	Keyhole
BF1	11	06/08/2002	**810**	SDSM&T	Keyhole
BF1	12	06/08/2002	**860**	SDSM&T	Keyhole
BF1	13	06/09/2002	710	SDSM&T	Keyhole
BF1	14	06/10/2002	300	SDSM&T	Keyhole
BF1	15	07/30/2002	**600**	SDSM&T	Routine
BF1	16	08/27/2002	100	SDSM&T	Routine
BF1	17	09/13/2002	260	SDSM&T	Routine
BF2	1	07/21/1999	**3,800**	DENR	Unknown
BF2	2	07/10/2000	340	DENR	Unknown
BF2	3	06/14/2001	**1,500**	SDSM&T	Routine
BF2	4	07/17/2001	**440**	DENR	Unknown
BF2	5	07/24/2001	**TNTC**[b]	SDSM&T	Rain
BF2	6	08/28/2001	66	SDSM&T	Routine
BF2	7	09/27/2001	250	SDSM&T	Routine
BF2	8	07/16/2002	**500**	DENR	Unknown
BF2	9	05/08/2003	100	DENR	Unknown

Table A-2. Detailed Water-Quality Data Less Than 5 Years Old From May 1 Until September 30 (Page 2 of 2)

Station	Count	Date	Fecal Coliform /100 ml	Government Agency[(a)]	Hydrologic Event
BF2	10	06/04/2003	60	DENR	Unknown
BF2	11	07/09/2003	**570**	DENR	Unknown
BF2	12	08/21/2003	210	DENR	Unknown
BF2	13	09/16/2003	150	DENR	Unknown
BF3	1	06/14/2001	140	SDSM&T	Routine
BF3	2	07/24/2001	**1,400**	SDSM&T	Rain
BF3	3	08/29/2001	18	SDSM&T	Routine
BF3	4	09/27/2001	110	SDSM&T	Routine
BF3	5	05/29/2002	300	SDSM&T	Routine
BF3	6	05/29/2002	320	SDSM&T	Routine
BF3	7	06/27/2002	250	SDSM&T	Routine
BF3	8	07/30/2002	0	SDSM&T	Routine
BF3	9	08/27/2002	30	SDSM&T	Routine
BF3	10	09/13/2002	220	SDSM&T	Routine

Notes:

Bold Values = Values exceeding the fecal coliform standard.

(a) SDSM&T data from Hoyer [2003]; DENR data from Splittstoesser [2004].

(b) TNTC = Too numerous to count.

Table A-3. Water-Quality Sampling Results From 2004 and 2005

Date	Flow (cfs)	Fecal Coliform cfu/100mL	TDS (mg/l)	TSS (mg/l)	Conductivity (mS/cm)	pH	Turbidity (NTU)	Water Temp (^{o}C)	DO (mg/l)
07/20/2004	19.5	**480**	1,800	22	1.753	8.18	12.0	27.61	8.98
07/28/2004	46.0	**730**	1,400	17	1.463	8.21	16.80	20.70	9.15
08/03/2004	71.6	**1,700**	1,300	200	1.590	8.04	90.0	—	—
08/18/2004	12.6	40	1,700	9	1.890	8.27	1.4	—	—
08/23/2004	(a)	**2,800**	1,700	5	2.254	(a)	62.1	18.41	2.56
05/09/2005	13.9	46	1,900	<5	2.238	8.06	17.8	14.54	9.29
05/17/2005	89.4	**600**	820	370	1,030	8.01	35.0	(a)	7.50
05/17/2005 Dup	—	**500**	790	400					
05/25/2005	24.4	**550**	1,000	41	1.358	8.08	62.40	15.70	7.83
06/01/2005	17.0	100	1,300	12					
06/09/2005	6.3	**530**	1,600	7	1.777	8.07	—	15.72	7.52
06/15/2005	12.5	26	3,400	<5	1.951	8.10	(1.10)	20.82	9.51
06/22/2005	7.2	120	1,900	<5	2.06	7.99	(5)	24.08	8.44
06/29/2005	5.8	**2,800**	940	230	0.98	7.58	228	18.25	8.21
07/05/2005	35.8	**460**	2,100	21	1.74	7.94	17.70	21.39	9.39
7/13/2005	32.3	360	1,500	<5	0.81	8.10	0.40	27.69	9.69
7/13/2005 Dup	—	290	1,500	<5	1.99	8.10	—	21.94	—
7/13/2005 Blank	—	ND	ND	ND					
8/8/2005	135	140	1,400	280	1.99	8.10	—	21.94	—

Notes:
Bold Values = Values exceeding the fecal coliform standard.
ND = not detected.

APPENDIX B

FECAL COLIFORM
FLUX modeling results

WQM 130, Belle Fourche River in Belle Fourche

```
Locating Sample File....
OPENING SAMPLE FILE = BF_WQ2.WK1
SAMPLE CONCENTRATION FIELD = FC
CONCENTRATION UNITS FACTOR =      100.000000
Flow Scale Factor =       .8937
Conc Scale Factor =    100.0000
Reading Samples...
Belle Fourche
NUMBER OF SAMPLES =         26
Reading Flows...
OPENING FLOW FILE = BF_FL2.WK1
FLOW FIELD = Flow
Belle Fourche
NUMBER OF FLOW RECORDS =       4045


 Belle Fourche                      VAR=FC        METHOD= 2 Q WTD C

 TABULATION OF MISSING DAILY FLOWS:

 Flow File =BF_FL2.WK1                       ,   Station =Flow
 Daily Flows from 19940408 to 20051204
 Flow Dates Missing   : 20041001 - 20050430
 Flow Dates Missing   : 20051004 - 20051005

 Summary:
 Reported Flows = 4045
 Missing Flows =   214
 Zero Flows =      121
 Positive Flows = 3924


 Belle Fourche                       VAR=FC        METHOD= 2 Q WTD C
 Comparison of Sampled & Total Flow Distributions
        ------ SAMPLED -----     ------- TOTAL ------
 STRAT   N     MEAN  STD DEV      N     MEAN  STD DEV     DIFF    T PROB(>T)
  1     26    53.62    55.20   4045   124.81   267.28   -71.19   6.13   .000
***     26    53.62    55.20   4045   124.81   267.28   -71.19   6.13   .000

 Average Sample Interval =  58.3 Days, Date Range = 20010614 to 20050808
 Maximum Sample Interval =   307 Days, Date Range = 20030916 to 20040720
 Percent of Total Flow Volume Occuring In This Interval =   2.7%

 Total Flow Volume on Sampled Days =        967.5 hm3
 Total Flow Volume on All Days     =     504863.1 hm3
 Percent of Total Flow Volume Sampled =      .2%

 Maximum Sampled Flow Rate =      244.87 hm3/yr
 Maximum Total Flow Rate   =     6711.38 hm3/yr
 Number of Days when Flow Exceeded Maximum Sampled Flow =472 out of 4045
 Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
       Maximum Sampled Flow Rate =    54.9%
```

Belle Fourche VAR=FC METHOD= 2 Q WTD C
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	4045	26	26	100.0	124.812	53.621	.394	.094
***	4045	26	26	100.0	124.812	53.621		

FLOW STATISTICS
FLOW DURATION = 4045.0 DAYS = 11.075 YEARS
MEAN FLOW RATE = 124.812 HM3/YR
TOTAL FLOW VOLUME = 1382.24 HM3
FLOW DATE RANGE = 19940408 TO 20051204
SAMPLE DATE RANGE = 20010614 TO 20050808

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	48225210.0	4354575.0	.3153E+13	34889.17	.408
2 Q WTD C	112253000.0	10136070.0	.9030E+13	81210.95	.296
3 IJC	114989400.0	10383150.0	.9642E+13	83190.59	.299
4 REG-1	156642500.0	14144300.0	.3699E+14	113325.20	.430
5 REG-2	274241500.0	24763090.0	.3162E+15	198403.70	.718
6 REG-3	159351500.0	14388910.0	.3458E+14	115285.00	.409

Belle Fourche VAR=FC METHOD= 2 Q WTD C
X =S FLOW , Y =CONC

BIVARIATE REGRESSION: Y VS. X

INTERCEPT =	3.8572	SLOPE =	.3944
R-SQUARED =	.1100	MEAN SQUARED ERROR =	.2877
STD ERROR OF SLOPE =	.2290	DEGREES OF FREEDOM =	24
T STATISTIC =	1.7221	PROBABILITY(>|T|) =	.0945
Y MEAN =	4.4521	Y STD DEVIATION =	.5571
X MEAN =	1.5086	X STD DEVIATION =	.4684

RESIDUALS ANALYSIS:

RUNS TEST Z =	1.0380	PROBABILITY (>|Z|) =	.1496
LAG-1 AUTOCORREL. =	-.0876	PROBABILITY (>|R|) =	.3275
EFFECTIVE SAMPLES =	26	SLOPE SIGNIFICANCE =	.0945

WQM 23, Redwater River near Belle Fourche

```
Locating Sample File....
OPENING SAMPLE FILE = WQ460895.WK1
SAMPLE CONCENTRATION FIELD = FC
CONCENTRATION UNITS FACTOR =      100.000000
Flow Scale Factor =       .8937
Conc Scale Factor =    100.0000
Reading Samples...
Redwater River near Belle Fourche
NUMBER OF SAMPLES =         31
Reading Flows...
OPENING FLOW FILE = FL460895.WK1
FLOW FIELD = Flow
Redwater River
NUMBER OF FLOW RECORDS =       8000
```

```
 Redwater River near BF            VAR=FC        METHOD= 2 Q WTD C

 TABULATION OF MISSING DAILY FLOWS:

 Flow File =FL460895.WK1                    ,   Station =Flow
 Daily Flows from 19831106 to 20050930

 Summary:
 Reported Flows = 8000
 Missing Flows =     0
 Zero Flows =        0
 Positive Flows = 8000
```

```
 Redwater River near BF            VAR=FC        METHOD= 2 Q WTD C
 Comparison of Sampled & Total Flow Distributions
        ------ SAMPLED -----     ------- TOTAL ------
 STRAT   N     MEAN  STD DEV      N     MEAN  STD DEV     DIFF    T PROB(>T)
  1     31    78.93    54.68   8000   128.85   109.44   -49.92   5.04   .000
***     31    78.93    54.68   8000   128.85   109.44   -49.92   5.04   .000

 Average Sample Interval =  63.0 Days, Date Range = 20000516 to 20050921
 Maximum Sample Interval =   251 Days, Date Range = 20040914 to 20050524
 Percent of Total Flow Volume Occuring In This Interval =   2.8%

 Total Flow Volume on Sampled Days =       2389.6 hm3
 Total Flow Volume on All Days     =    1030820.0 hm3
 Percent of Total Flow Volume Sampled =      .2%

 Maximum Sampled Flow Rate =      218.96 hm3/yr
 Maximum Total Flow Rate   =     3744.60 hm3/yr
 Number of Days when Flow Exceeded Maximum Sampled Flow =583 out of 8000
 Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
       Maximum Sampled Flow Rate =    19.6%
```

```
Redwater River near BF            VAR=FC        METHOD= 2 Q WTD C
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1      8000  31  30 100.0      128.853       78.928       -.429   .030
***      8000  31  30 100.0      128.853       78.928

 FLOW STATISTICS
 FLOW DURATION =    8000.0 DAYS  = 21.903 YEARS
 MEAN FLOW RATE =   128.853 HM3/YR
 TOTAL FLOW VOLUME =    2822.23 HM3
 FLOW DATE RANGE   = 19831106 TO 20050930
 SAMPLE DATE RANGE = 20000516 TO 20050921

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD     13159330.0       600805.7      .1121E+11    4662.74    .176
 2 Q WTD C     21482990.0       980832.9      .2739E+11    7612.06    .169
 3 IJC         21350910.0       974802.4      .2782E+11    7565.26    .171
 4 REG-1       17407330.0       794753.2      .2832E+11    6167.93    .212
 5 REG-2       16860320.0       769779.1      .2626E+11    5974.11    .211
 6 REG-3       19789900.0       903532.4      .4445E+11    7012.14    .233


Redwater River near BF            VAR=FC        METHOD= 2 Q WTD C
X =S FLOW   , Y =CONC

BIVARIATE REGRESSION:  Y VS. X
 INTERCEPT          =      4.5641  SLOPE              =      -.4292
 R-SQUARED          =       .1486  MEAN SQUARED ERROR =       .1736
 STD ERROR OF SLOPE =       .1908  DEGREES OF FREEDOM =          29
 T STATISTIC        =     -2.2499  PROBABILITY(>|T|)  =       .0304
 Y MEAN             =      3.8082  Y STD DEVIATION    =       .4440
 X MEAN             =      1.7609  X STD DEVIATION    =       .3987
RESIDUALS ANALYSIS:
 RUNS TEST Z        =     -1.3504  PROBABILITY (>|Z|) =       .0884
 LAG-1 AUTOCORREL.  =       .0746  PROBABILITY (>|R|) =       .3389
 EFFECTIVE SAMPLES  =          26  SLOPE SIGNIFICANCE =       .0478
```

APPENDIX C

BELLE FOURCHE RIVER FECAL COLIFORM BACTERIA TOTAL MAXIMUM DAILY LOAD DOCUMENT

TOTAL MAXIMUM DAILY LOAD EVALUATION OF FECAL COLIFORM BACTERIA FOR THE IMPAIRED SEGMENT OF THE BELLE FOURCHE RIVER (From the Wyoming Border to Near Fruitdale, SD)

(HUC 10120202)

Butte County, South Dakota

South Dakota Department of Environment and Natural Resources

December, 2007

BELLE FOURCHE RIVER FECAL COLIFORM BACTERIA TOTAL MAXIMUM DAILY LOAD DECEMBER, 2007

Waterbody Type: River

303(d) Listing Parameter: Fecal coliform bacteria

Designated Uses: Warmwater permanent fish propagation
Immersion recreation
Limited contact recreation
Fish and wildlife propagation, recreation, and stock watering
Irrigation

Size of Impaired Waterbody: 46 stream miles (in South Dakota)

Size of Watershed: 461,878 acres (in South Dakota)

Water-Quality Standards: Narrative and Numeric

Indicators: Fecal coliform bacteria concentrations

Analytical Approach: Load duration curves and FLUX load modeling

Location: HUC Code: 10120202

Goal: Reduce fecal coliform bacteria load above the confluence with the Redwater River by 51%

Target: Fecal coliform bacteria concentration ≤ 400 cfu/100 mL

Reach Number: SD-BF-R-BELLE_Fourche_01

OBJECTIVE

The intent of this summary is to clearly identify the components of the total maximum daily load (TMDL) submittal, to support adequate public participation, and to facilitate the US Environmental Protection Agency (EPA) review and approval. This TMDL was developed in accordance with Section 303(d) of the Federal Clean Water Act and guidance developed by EPA.

INTRODUCTION

The Belle Fourche River is a natural stream that drains portions of Butte, Lawrence, and Meade Counties in South Dakota (Figure C-1). The Belle Fourche River Watershed is approximately 2,100,000 acres (3,300 miles^2) in South Dakota and approximately 2,400,000 acres (3,700 miles^2) in Wyoming. Land use in the Watershed includes cattle grazing, farming, mining, timber production, hunting, and other recreation. Approximately 84 percent of the Watershed is rangeland and 10 percent is agricultural.

RSI-1498-06-004

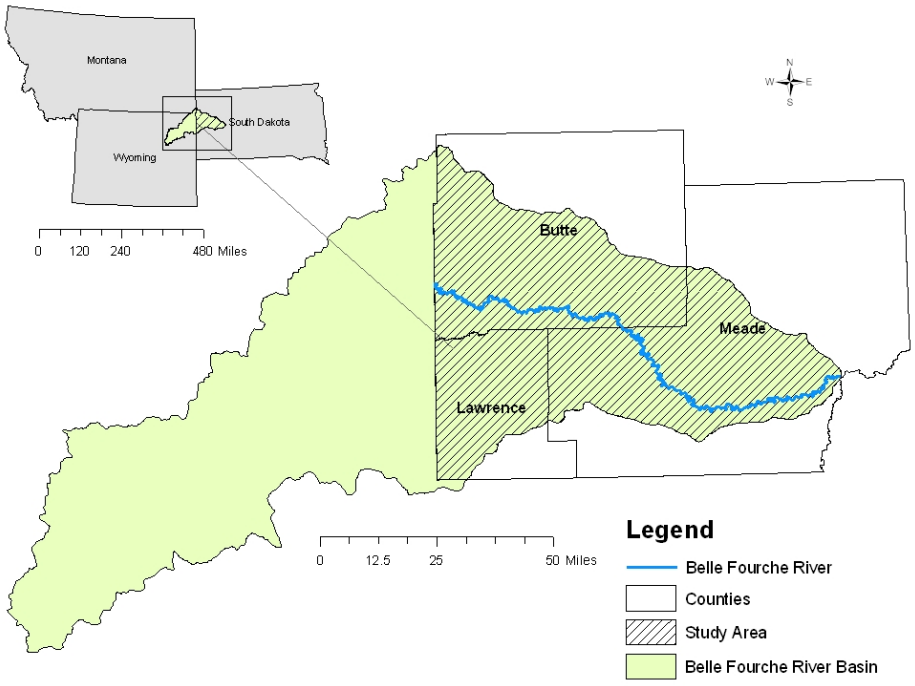

Figure C-1. Location of the Belle Fourche River Watershed in Butte, Lawrence, and Meade Counties, South Dakota.

PROBLEM IDENTIFICATION

The Belle Fourche River carries an excessive fecal coliform bacteria load that degrades the water quality of the river. Approximately 1.01×10^{15} colony-forming units (cfu)/year of fecal coliform bacteria are transported in the Belle Fourche River from the Wyoming border to the confluence of the Red Water River, as estimated at Water Quality Monitoring (WQM) Station 130 (Figure C-2).

RSI-1498-06–005

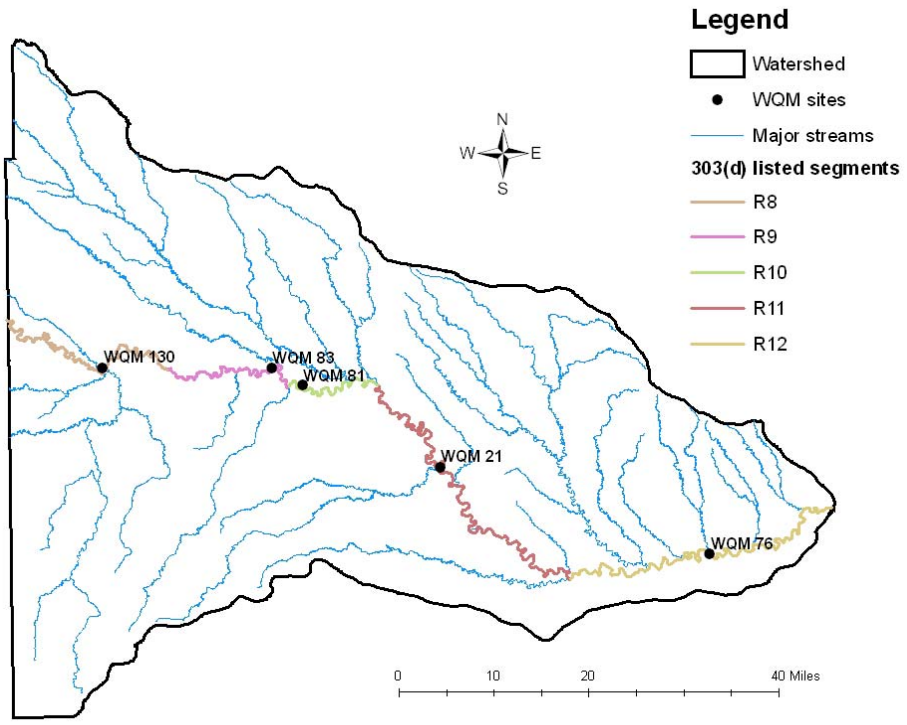

Figure C-2. 303(d) Listed Segments of the Belle Fourche River (From South Dakota Department of Environment and Natural Resources 2004 Integrated Report for Surface Water Quality Assessment) and Location of Water-Quality Monitoring Stations (WQM Sites) Established by the South Dakota Department of Natural Resources Surface Water-Quality Program.

The Belle Fourche River is identified in the 2004 and 2006 *South Dakota Integrated Report for Surface Water Quality Assessment* as impaired due to elevated fecal coliform bacteria concentrations. These listings have been assigned high priority status due to the widespread local support for water-quality improvement.

According to the 2004 and 2006 South Dakota Integrated Report for Surface Water Quality Assessment, the Belle Fourche River from the Wyoming border to near Fruitdale failed to support its assigned uses because

of high fecal coliform bacteria. The report states that agricultural activities (e.g., livestock grazing in riparian zones) are deemed a likely source of occasional impairment.

The 2004 Integrated Report divides the river into five segments (R8, R9, R10, R11, and R12) based on the location of South Dakota Department of Environment and Natural Resources (SD DENR) Surface Water Quality Program's ambient WQM sites (see Figure C-2). Only R8 was identified as impaired due to high fecal coliform concentrations. Data collected by SD DENR at WQM 130, in addition to the data collected at this site during the watershed assessment, were used to calculate a total maximum daily load (TMDL) for the listed segment of the Belle Fourche River.

DESCRIPTION OF APPLICABLE WATER-QUALITY STANDARDS AND NUMERIC WATER-QUALITY TARGETS

The Belle Fourche River has been assigned beneficial uses by the state of South Dakota Surface Water Quality Standards regulations. Along with these assigned uses are narrative and numeric criteria that define the desired water quality of the river. These criteria must be maintained for the river to satisfy its assigned beneficial uses, which are listed below:

- Warm water permanent fish propagation
- Immersion recreation
- Limited contact recreation
- Fish and wildlife propagation, recreation, and stock watering
- Irrigation waters.

Individual parameters, including fecal coliform bacteria concentrations, determine the support of beneficial uses and compliance with standards. In the case where there is more than one applicable criterion for a water-quality constituent, the most stringent of these criteria is used. For immersion recreation waters, the 30-day geometric mean (based on a minimum of five samples obtained during separate 24-hour periods for any 30-day period) concentration of fecal coliform bacteria samples should not exceed 200 cfu/100 ml or a daily maximum concentration of 400 cfu/100 ml. Fecal coliform bacteria concentrations in the Belle Fourche River have been found to exceed the daily maximum fecal coliform standard.

POLLUTANT ASSESSMENT

POINT SOURCES

Several municipalities are located within the Belle Fourche River Watershed, including Belle Fourche, Central City, Deadwood, Fruitdale, Lead, Newell, Nisland, Spearfish, Sturgis, Vale, and Whitewood.

Spearfish is the only municipality within the Belle Fourche River Watershed that has a point-source discharge permit for wastewater treatment effluent that affects the listed reach of the river. All other municipalities within the Watershed either have coverage under a no-discharge permit or are downstream of the impaired reach.

NONPOINT SOURCES

Sampling included in this project indicated that nonpoint sources of fecal coliform bacteria include sources from natural background; specifically, from wildlife within the Watershed. Runoff from the city of Belle Fourche likely adds fecal coliform to the Belle Fourche River. Agricultural sources of fecal coliform, specifically from cattle, were not identified in this project (based on limited bacterial source tracking samples); however, it is likely that there is some degree of loading from this source. It appears that human sources are not a significant portion of the nonpoint sources of fecal coliform bacteria (based on limited bacterial source tracking samples).

TOTAL MAXIMUM DAILY LOAD AND ALLOCATIONS

TOTAL MAXIMUM DAILY LOAD

A TMDL is defined as the total amount of pollution a waterbody can assimilate and still maintain water-quality standards. A TMDL includes the sums of the waste load allocations from point sources; the load allocations from nonpoint sources, including natural background sources; and a margin of safety to account for sources of uncertainty.

A TMDL was calculated for the listed segment of the Belle Fourche River. FLUX, a program developed by the U.S. Army Corps of Engineers, was used to estimate the current fecal coliform load at WQM 130. To determine the TMDL for the listed segment, the FLUX model was run using the standard for fecal coliform, 400 cfu/100 ml for WQM 130. Additionally, a load allocation (LA) was calculated for the Redwater River, which enters the Belle Fourche River downstream of WQM 130. The LA for the Redwater River was calculated using FLUX at WQM 23 using the fecal coliform standard of 400 cfu/100 ml in the same manner as WQM 130. The LA for the Redwater was adjusted to account for the waste load allocation (WLA) for the city of Spearfish, whose discharge eventually enters the Redwater River. TMDL allocations are shown in Table C-1.

Table C-1. TMDL for Reach 8 of the Belle Fourche River (cfu/day)

Reach 8, Belle Fourche River	
Load Allocation (LA)	2.45E+12
Waste Load Allocation (WLA)	
City of Spearfish	4.85E+10
Margin of Safety (MOS)	
Explicit (10 percent of TMDL)	2.78E+11
Total Maximum Daily Load (TMDL)	2.78E+12

A goal of 46-percent reduction of the annual fecal coliform load was set for Reach 8 of the Belle Fourche River based on loading found at WQM 130. This goal will meet or exceed the required reductions for each listed segment of the Belle Fourche River. The calculation of the needed percent reduction is discussed further in the Load Allocation section of this document.

WASTELOAD ALLOCATIONS (WLA)

The WLA portion of the TMDL identifies the portion of the loading capacity allocated to existing and future point sources. There is one permitted point source of fecal coliform in the Belle Fourche River Watershed. The individual point source estimate for the WLA was calculated using system design flow rates and effluent limit concentrations for the permitted facility.

Based on permit limits and system design peak flow rates, the point source discharge facility (city of Spearfish) in the Belle Fourche River Watershed can discharge approximately 4.85×10^{10} cfu/day of fecal coliform. This is a conservative estimate, since currently Spearfish is not discharging the maximum allowed. To add an implicit margin of safety, no decay rate was added to the WLA allocation for Spearfish for the length of streams and rivers between the city of Spearfish and the confluence of the Redwater River and the Belle Fourche River.

LOAD ALLOCATIONS

The LA portion of the TMDL identifies the portion of the loading capacity allocated to existing and future nonpoint sources. Natural background sources are included in the nonpoint source load allocation to represent the portion of the loading capacity attributed to wildlife. The LA was calculated as the allowable annual load based on the annual mean flow of the Belle Fourche River at WQM 130 calculated from FLUX plus the allowable annual load based on the annual mean flow of the Redwater River at WQM 23 calculated from FLUX. The allowable annual loads were calculated by multiplying the estimated mean annual flow by the fecal

coliform standard of 400 cfu/100 ml. The WLA calculated for the city of Spearfish was subtracted from the LA for the Redwater River so the WLA load was not accounted for twice in the TMDL calculation. Daily load estimates were calculated from annual flow and load estimates by dividing by 365.

Based on the estimated annual loading at WQM 130, a reduction of 1.41×10^{12} cfu/day (51 percent) is required to meet the water-quality standard above the confluence of the Redwater River. This load reduction represents a 46-percent reduction of the estimated annual load for the downstream end of R8 of the Belle Fourche River. The TMDL estimate for the downstream end of Reach 8 of the Belle Fourche River was calculated by adding the FLUX loading estimates for WQM 130 and WQM 23 together. It should be noted that the Redwater River is currently meeting its fecal coliform standard and requires no further reduction. Best Management Practices (BMPs) implemented in order to meet the TMDL need to be focused on the Belle Fourche River upstream of the confluence of the Redwater River since this is where the highest concentrations were measured. Any BMPs focused on the Watershed below the confluence of the Redwater River or in the Redwater River Watershed may reduce the concentration of fecal coliform bacteria and work toward achieving the TMDL at the bottom of Reach 8; however, they will not be effective in the critical reach, meaning the Belle Fourche River would still be in violation of the water-quality standard.

The required reductions of fecal coliform concentrations may be achieved through the implementation of BMPs, including filter strips, riparian buffer strips, and riparian zone rehabilitation. These practices should be effective in reducing fecal loading from overland sources, either from cattle or wildlife. Also, a litter control program should be implemented in the municipality of Belle Fourche. Litter control programs have been shown to reduce fecal loading in urban areas by up to 50 percent [Novotny and Olem, 1994][1]. Lastly, BMPs traditionally used for cattle sources of fecal coliform, such as fencing and exclusion, off-site watering, and rotational grazing, should be implemented. Even though no direct evidence from bacterial source tracking was documented of livestock (predominantly cattle and sheep) sources for fecal coliform bacteria, the results are inconclusive because of the small sample size. It is likely that some fecal coliform loading is being contributed by livestock sources. BMPs focused on livestock sources will lower the fecal coliform loading since they will be effective at lowering concentrations of fecal coliform bacteria from livestock sources in the Watershed. Additionally, many of the same BMPs (e.g., filter strips) should be effective in lowering concentrations of fecal coliform bacteria from wildlife sources.

MARGIN OF SAFETY

Substantial uncertainty is often inherent in estimating fecal coliform loads from nonpoint sources. To account for uncertainty in the TMDL calculations, a portion of the available fecal coliform loading capacity was not allocated. Ten percent of the TMDL was reserved as the margin of safety, a required component of the TMDL.

[1] **Novotny, V. and H. Olem, 1994.** *Water Quality: Prevention, Identification, and Management of Diffuse Pollution*, Van Nostrand Reinhold, New York, NY.

FOLLOW-UP MONITORING

Future monitoring will be necessary to determine whether or not the proposed implementation actions have had an impact on water quality in the Belle Fourche River Watershed. Once the implementation project is completed, postimplementation monitoring will be necessary to ensure that the TMDL was reached. At a minimum, quarterly monitoring will continue for WQM 130. Additional bacteria source tracking may be necessary to better understand the sources of fecal coliform bacteria. Presently, the contribution of human and cattle sources is not clearly understood. Source tracking on this project indicated animals other than cattle are the major source of loading. Future source tracking should focus on identifying the specific animal sources contributing to fecal coliform loading. This will lead to better, more effective BMPs to be implemented. Finally, more samples upstream and downstream of the city of Belle Fourche need to be collected to better understand the impacts of Belle Fourche on water quality. Data collected on this project showed conflicting trends over the reach of the river containing inflow from the city of Belle Fourche.

PUBLIC PARTICIPATION

Efforts were taken to gain public education, review, and comment during development of the TMDL, including local newspaper articles, general public meetings, Technical Group meetings, and Belle Fourche River Watershed Partnership meetings. The general public meetings provided an opportunity to present assessment results and to receive input from the stakeholders. The comments/findings from these public meetings were taken into consideration in the development of the Belle Fourche River TMDL.

IMPLEMENTATION PLAN

The Belle Fourche River Watershed Partnership is the project sponsor of a 2-year implementation project. This project is set to start in the spring of 2006. This is the third segment of seven planned project segments addressing a cluster of nine TMDLs. Completion of the activities planned for this segment will advance the BMP implementation for total suspended solids (TSS) pollutants to 21 percent completed. This project will continue implementation of the BMPs identified in the TSS TMDL report for the Belle Fourche River Watershed. These BMPs include implementing grazing management systems and installing riparian vegetation improvements which will also benefit the fecal coliform loading to the Belle Fourche River. Future segments of the Belle Fourche River Implementation Project will specifically address the fecal coliform loading to Reach 8 of the Belle Fourche River.